R&D towards a multi-kTon modular single phase LArTPC

ELBNF 35ton Prototype

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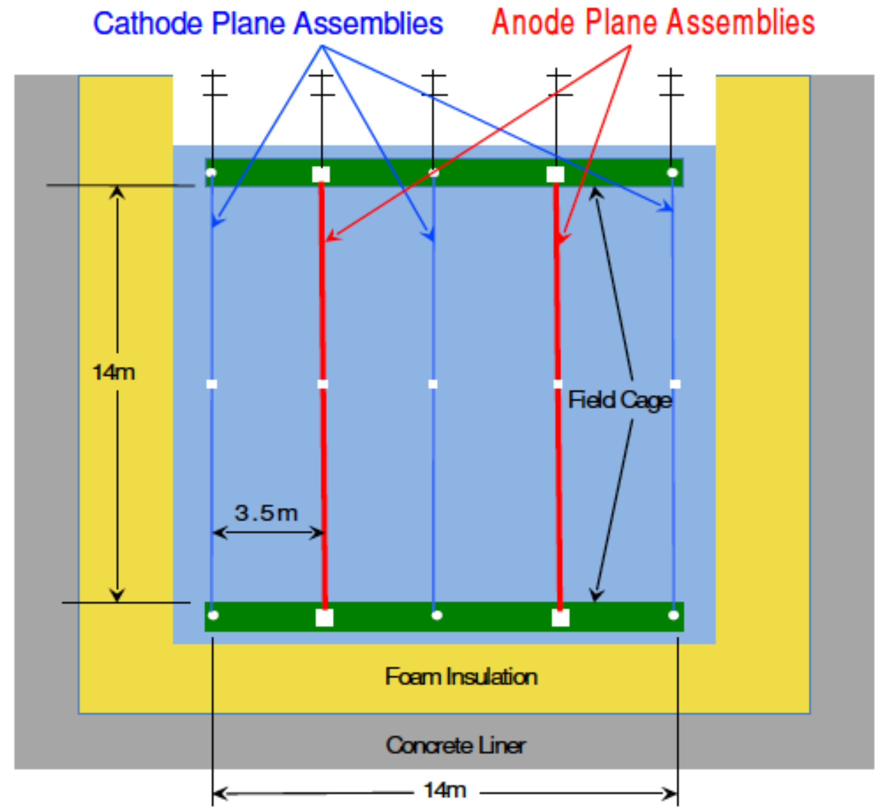
LAr1-ND Collaboration Meeting
11 March 2015

Fermilab

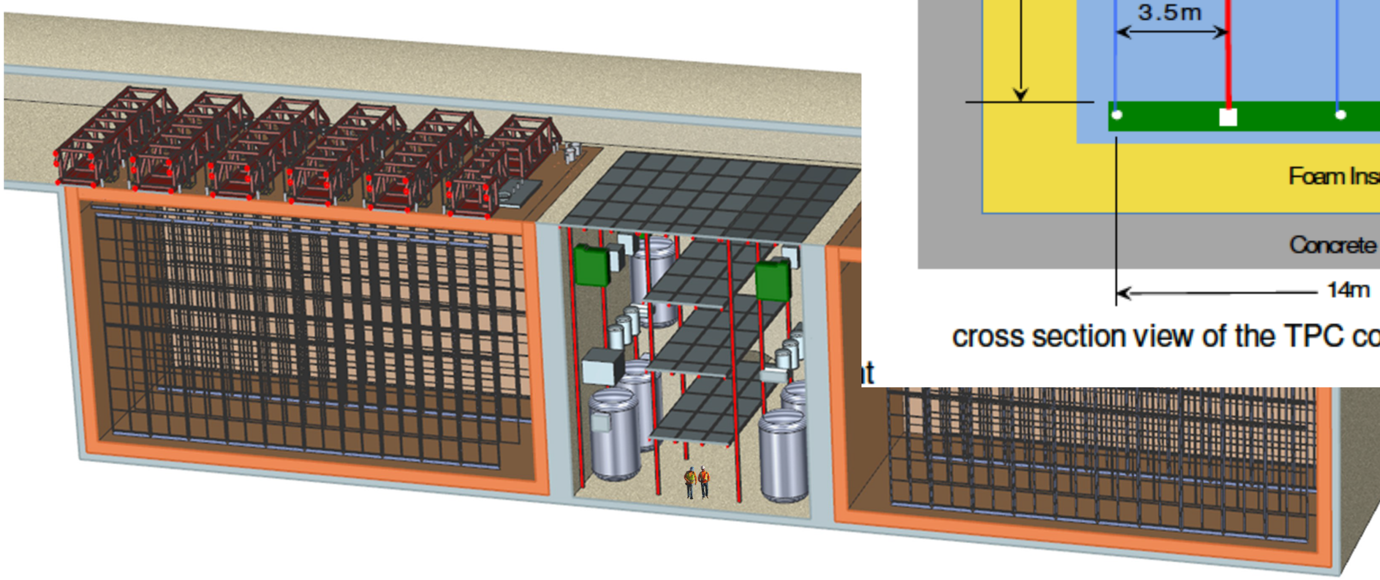
U.S. DEPARTMENT OF ENERGY | Office of Science

Multi-kTon underground LAr Far Detector for ELBNF

- Single phase TPC option: GIANT leap in scale from ICARUS (0.6 kTon)



cross section view of the TPC components inside the cryostat



Some issues that arise when scaling up at Homestake

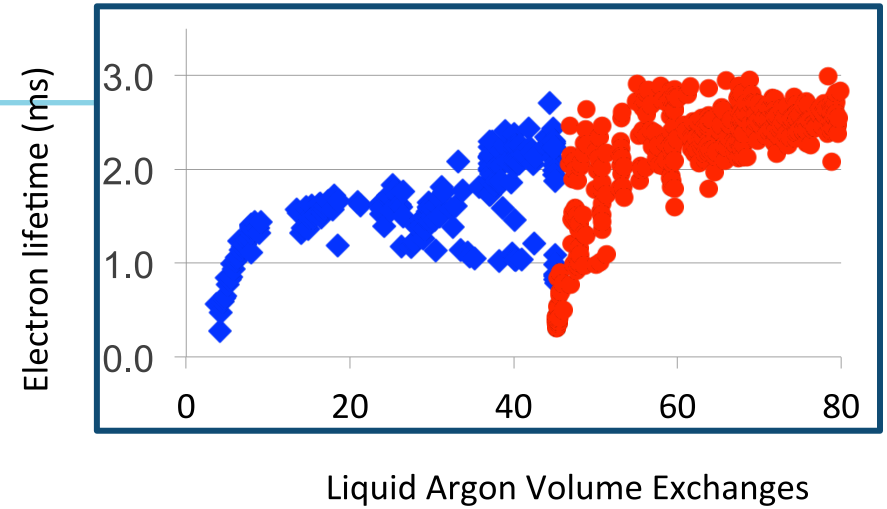
- Cathode HV: 175-200 kV for 3.5-4.0 m drift
- Field cage – steel “pipe” design is manpower-intensive
- Modular TPC design is a must - need to minimize losses in gaps between modules
- Photon detection - explore alternatives to PMTs that can reduce cost and lost fiducial volume
- Cryostat – needs be assembled from pieces that can fit in mine shaft (membrane cryostat)
- Readout and DAQ
  - need to digitize and multiplex TPC data “in the cold”
  - triggerless operation desired for non-beam physics, in particular supernovas

Need to test possible solutions!

35-ton Prototype Goals

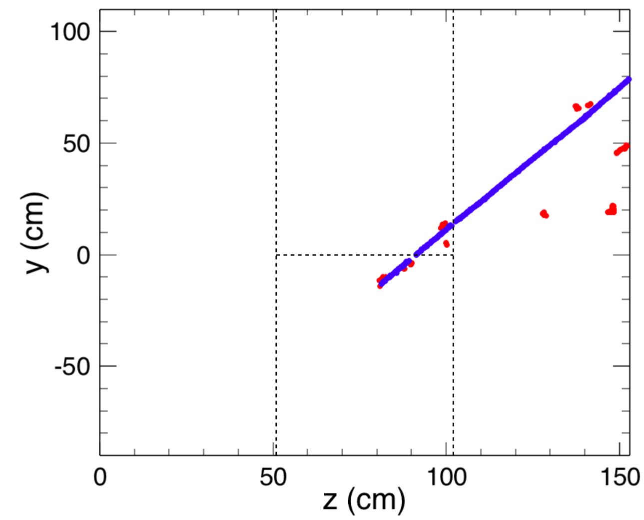
Phase-I (No TPC, 2014)

- Validation of membrane cryostat design/performance
- Demonstrate argon purity required for physics



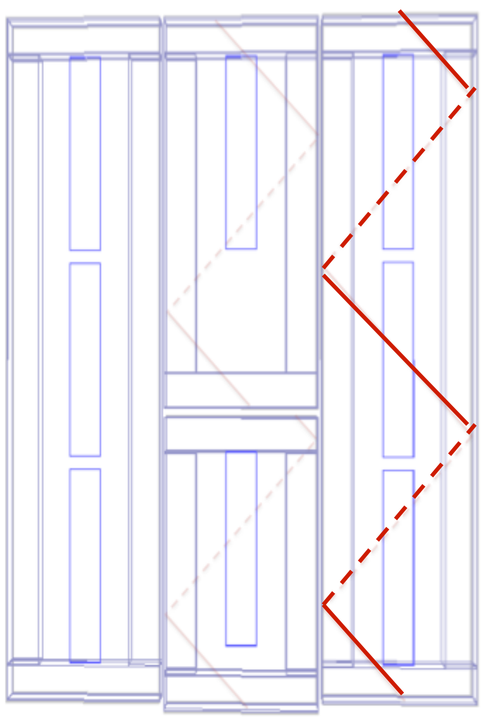
Phase-II (Cosmic rays, Summer 2015)

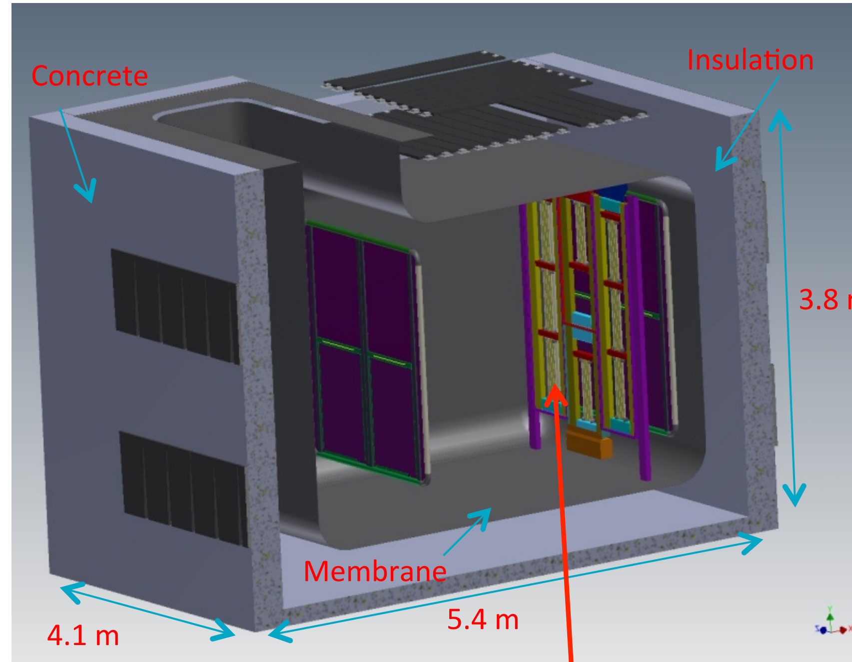
- Modular TPC performance:
  - wrapped wires
  - gaps between modules
  - tracks crossing APAs
- Bar+SiPM photon detectors
- Field Cage: FR4 printed circuit board
- Electronics/DAQ
  - cold pre-amp and ADC
  - triggerless operation (continuous readout)
  - zero suppression development

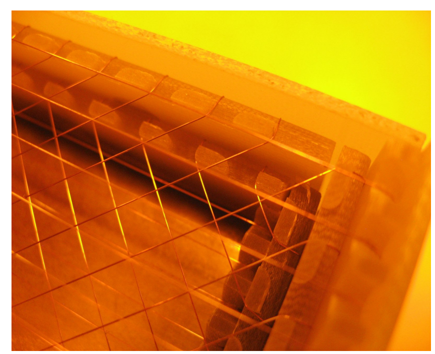


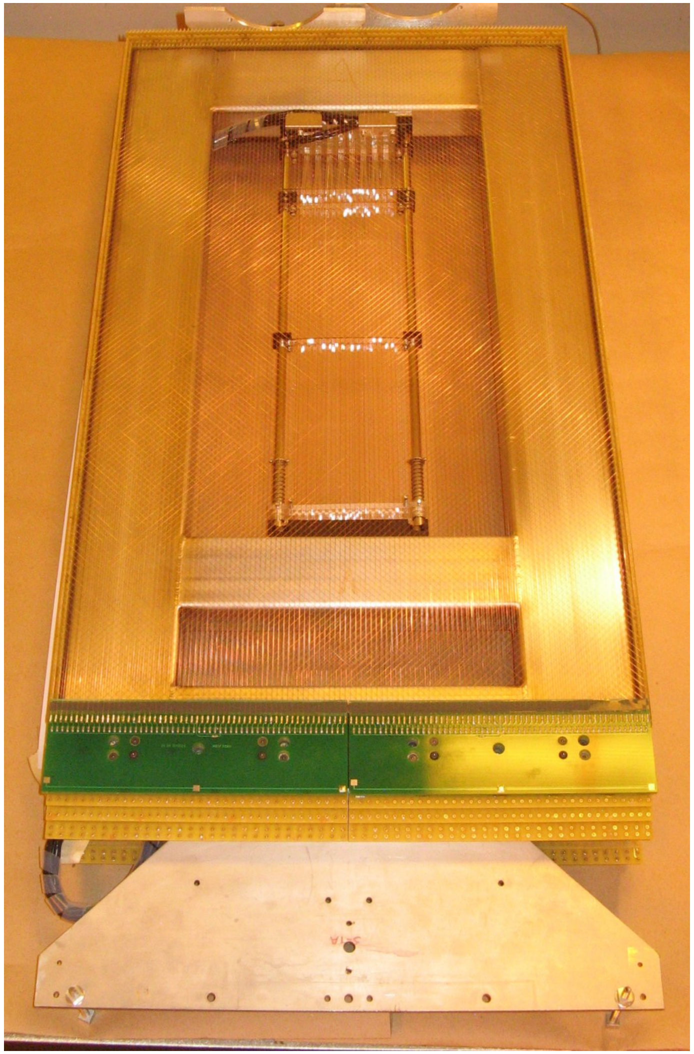
35ton Prototype Phase 2

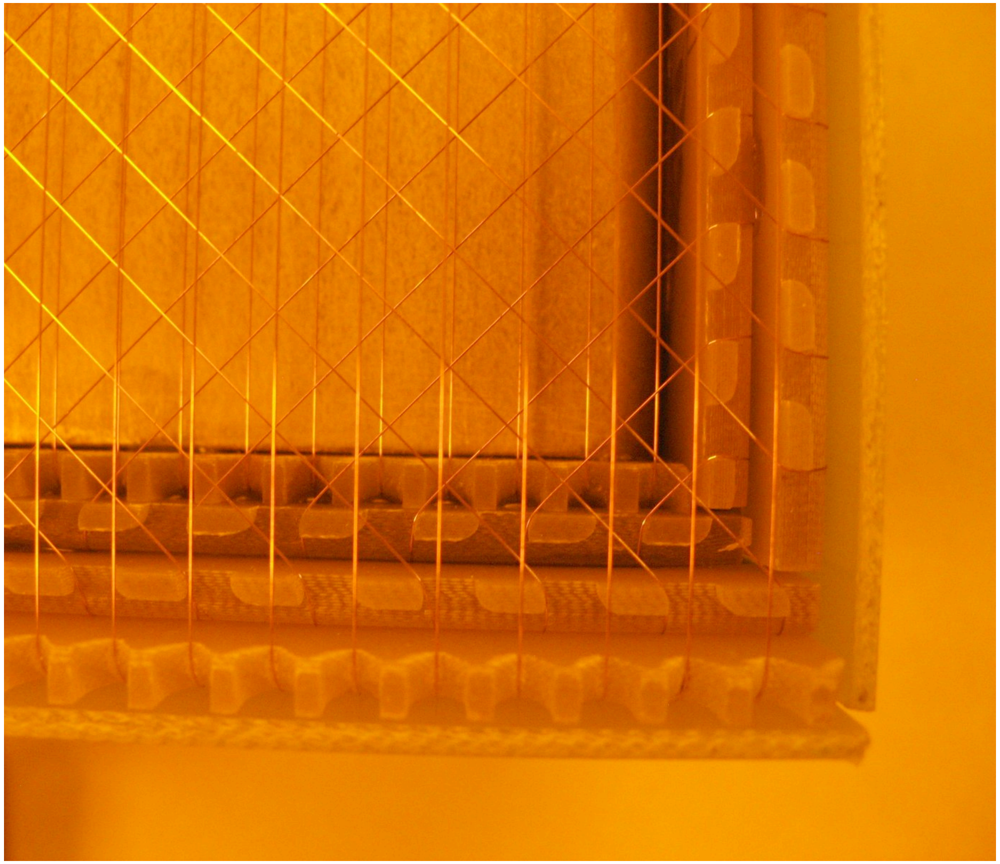
- 2.5m x 1.5m x 2m active volume
- Two drift volumes (long/short)
- 4 APA modules (8 sets of wires)



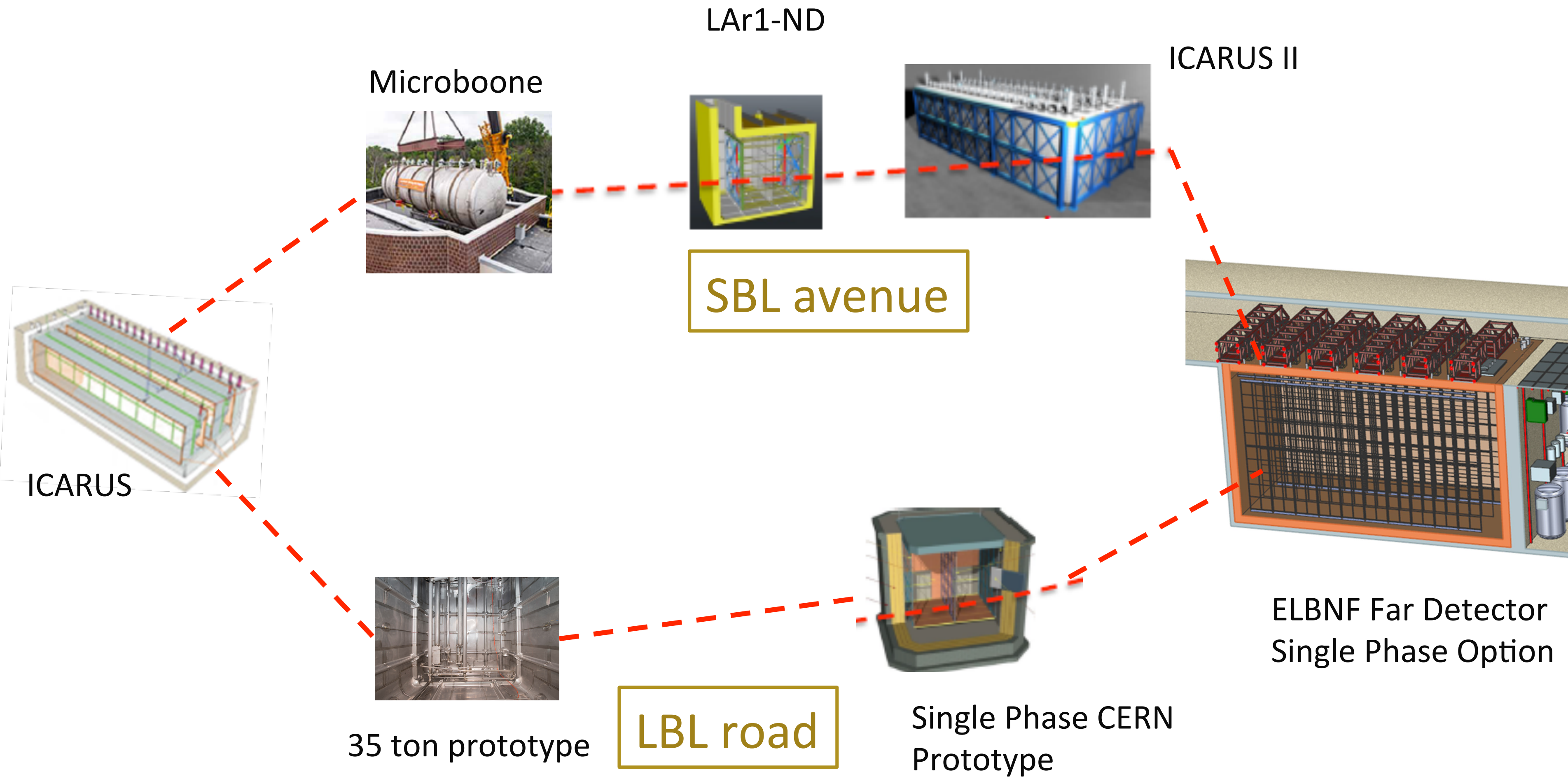






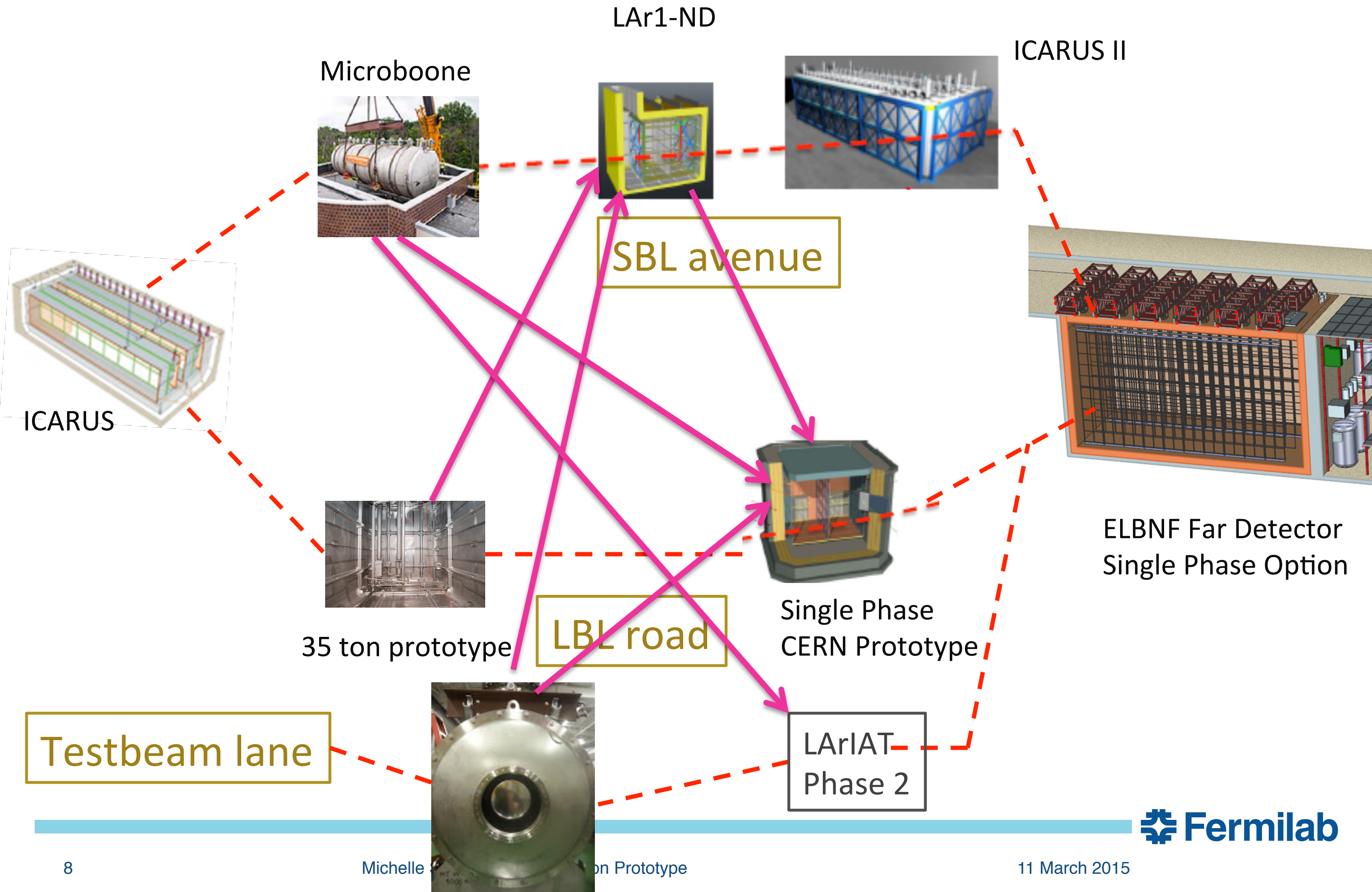


Evolution: the road to 10 kton by 2023 is challenging

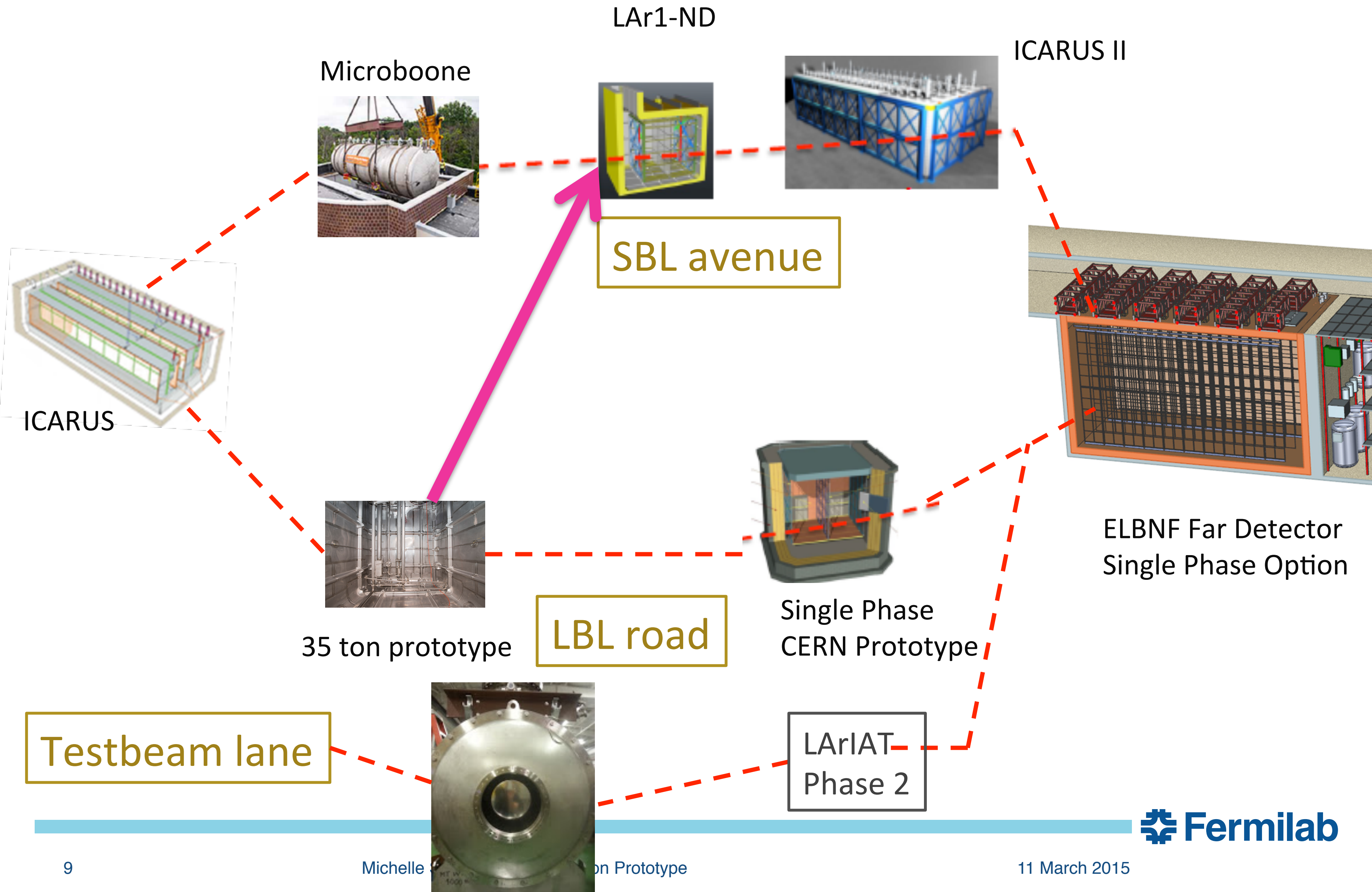


Slide from Mark Thomson

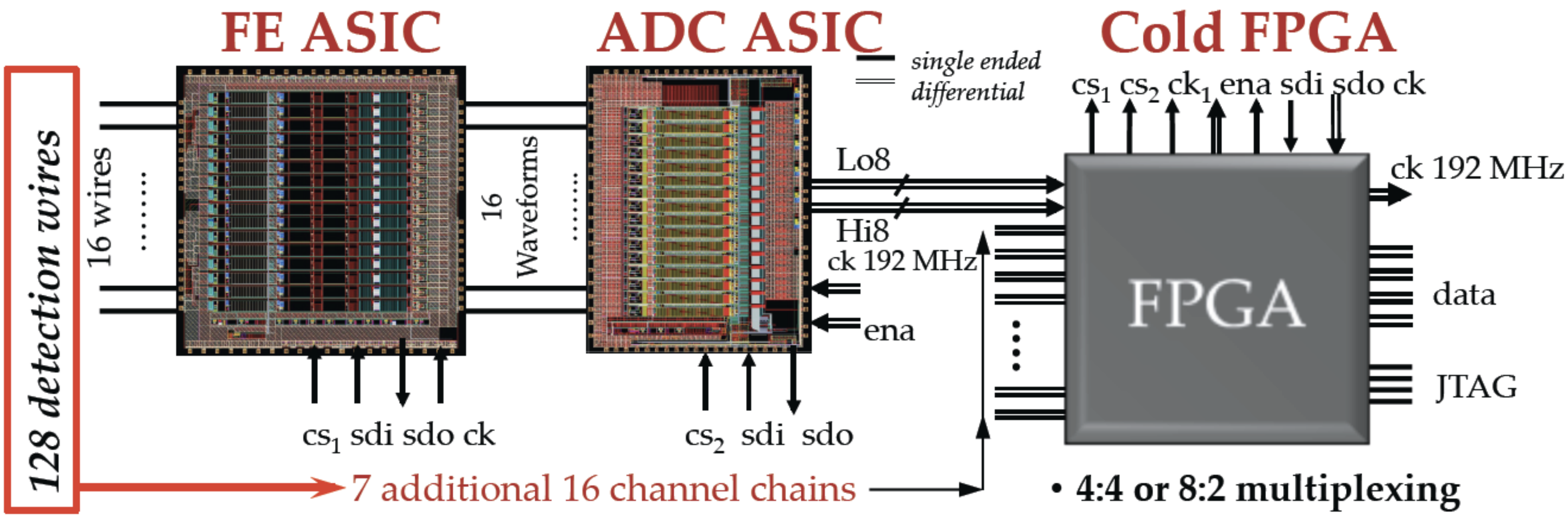
But these aren't isolated roads . . .



Rest of the talk focuses on moving information this way . . .



Key Components of the Cold Electronics (H. Chen)



- low-noise analog amplification
- programmable gain, shaping, coupling, …
- charge calibration over all chips, channels and temperatures to 1%

- ADC 12-bit 2MS/s sampling rate
- built-in FIFO
- serialized outputs
- 2 x **8:1 multiplexing**

- **4:4 or 8:2 multiplexing** (total 32:4 or 64:2)
- timestamp
- compression
- zero suppression
- neighbor triggering
- *support non-reduction transparent mode*
- *max output data rate 960Mbit/s or 1.92Gbit/s with overhead of 8B/10B*

Things to watch for LAr1-ND design

Cold Electronics

- Failures, reliability, lessons learned
- Noise, S/N optimization

DAQ

- Zero suppression as (emergency) alternative to lossless compression. Algorithm testing in the 35 ton is enabled by high throughput of RCEs from SLAC
- ARTDAQ for data acquisition, online monitoring, perhaps online filtering

Field Cage

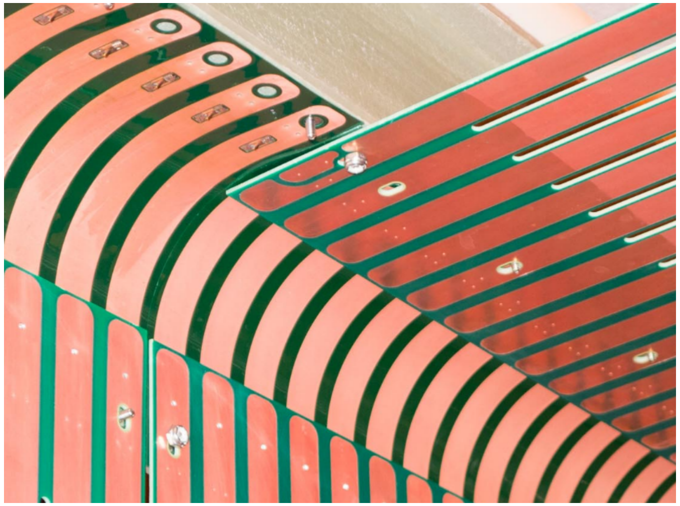
Photon Detectors

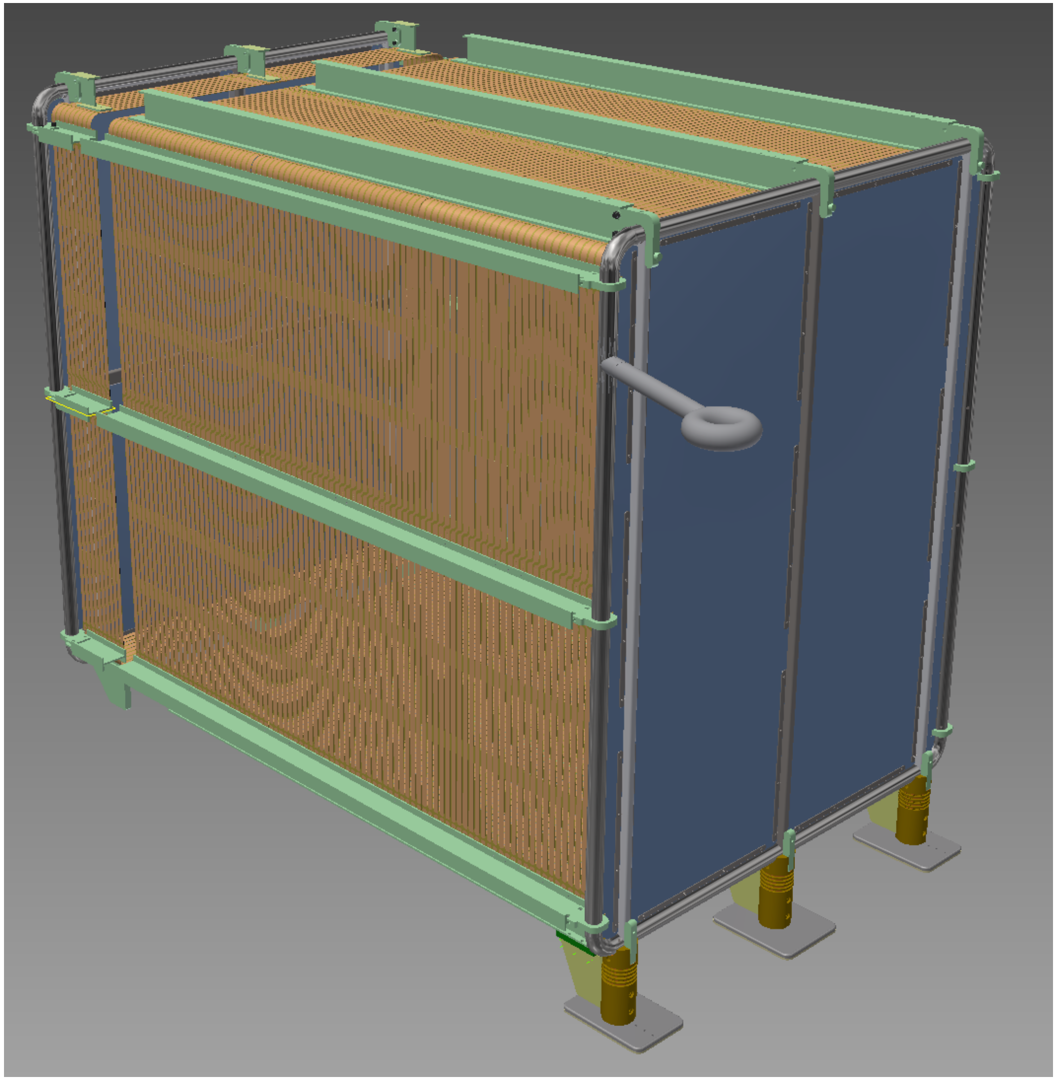
Gaps between modules

Space Charge studies and Fluid flow models

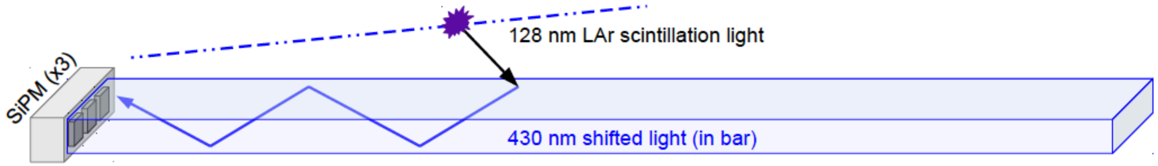
TPC Design Features: Field Cage

- FR4 printed circuit board based construction.
- All Edges of the copper strips are covered by solder mask to reduce high field exposure in LAr.
- Integrated inter-strip capacitors to minimize over voltage condition in a spark
- 0.2mm thick FR4 used for the rounded field cage corners.

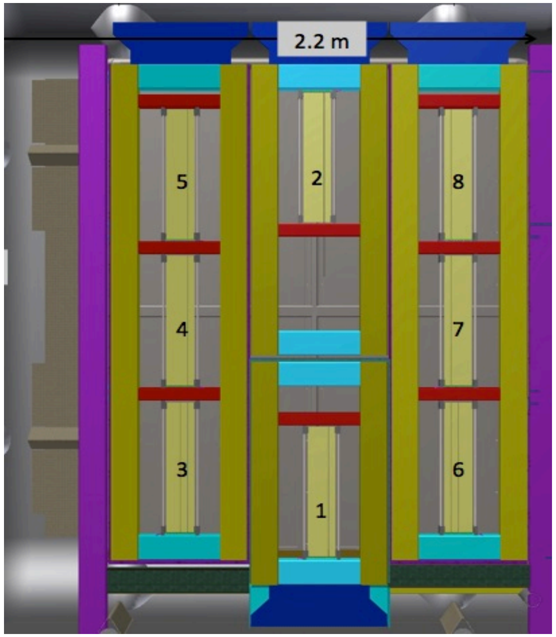


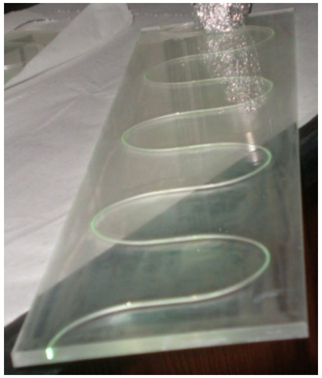


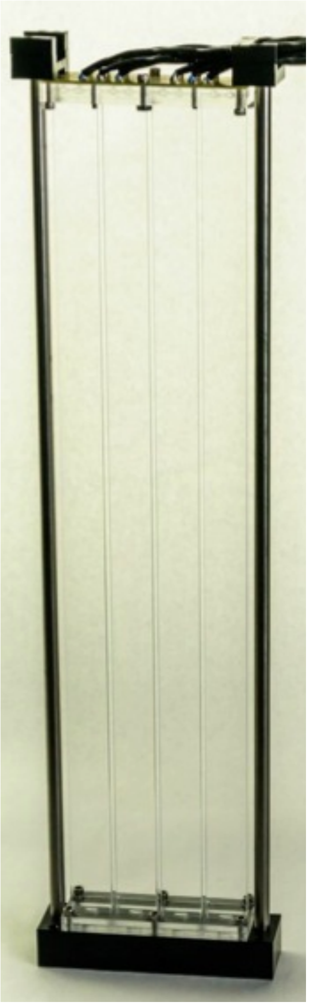
Photon Detectors



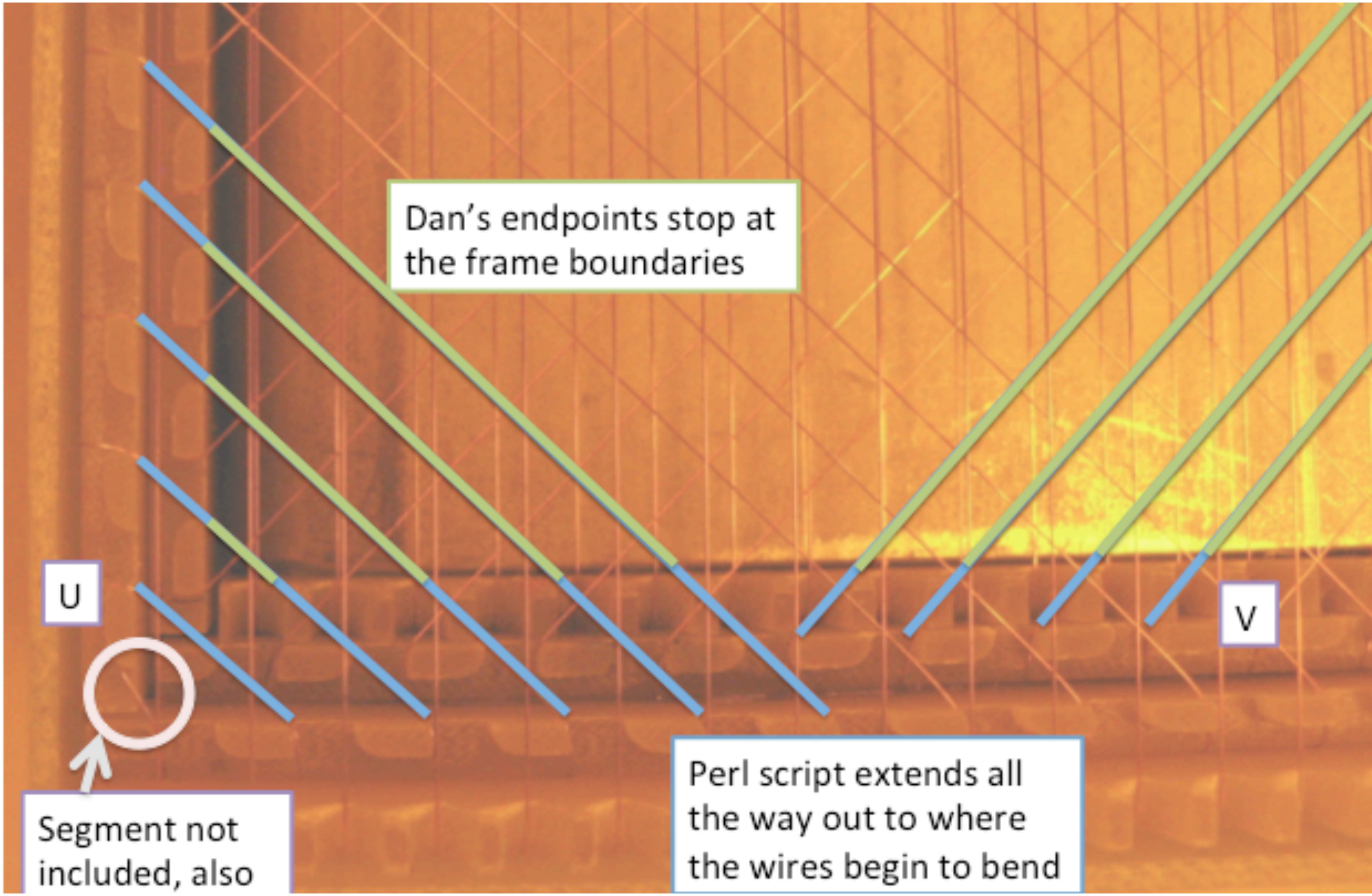
- The 35T Photon Detector (PD) system consists of 8 individual PD Modules, arranged in the configuration shown to the right.
- While the photon detector technology preliminary selection has been made (sensL MicroFB 60035-SMT), the light collection technology down select still has not.
- 3 significant design revisions of PD module will be tested in the 35T detector:
  - Four modules of the nominal “4-bar” configuration testing several different wavelength shifting technologies (positions 2,3,5,7)
  - Three modules of the “32 Fiber PD” configuration (positions 1,4,8)
  - One module of the “Fiber embedded plate” configuration (position 6)
- Each PD module has a detector active area of approximately 500mmx100mm.







APA gaps: signal simulation (Tom Junk)



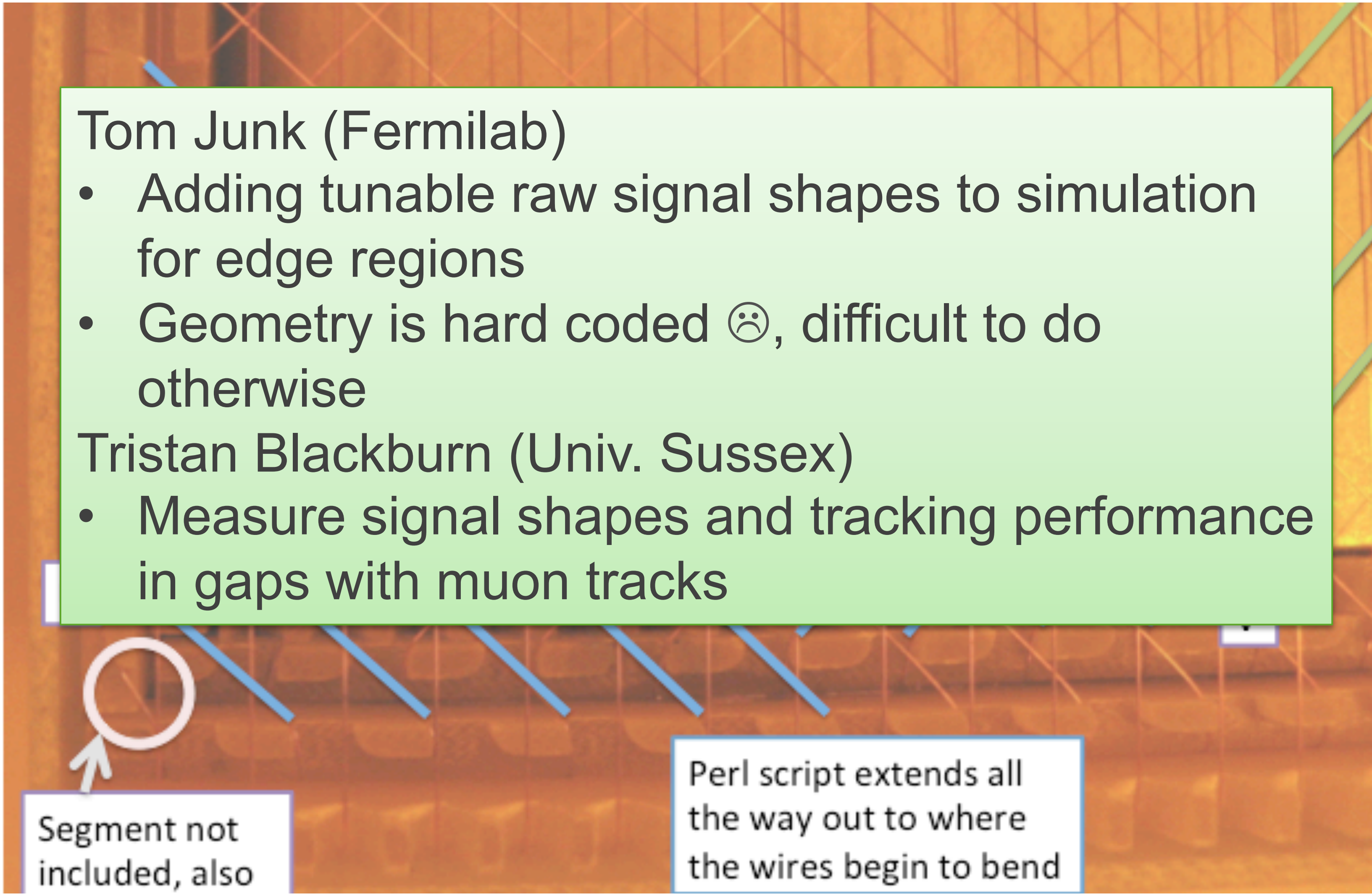
APA gaps: signal simulation (Tom Junk)

Tom Junk (Fermilab)

- Adding tunable raw signal shapes to simulation for edge regions
- Geometry is hard coded ☹, difficult to do otherwise

Tristan Blackburn (Univ. Sussex)

- Measure signal shapes and tracking performance in gaps with muon tracks

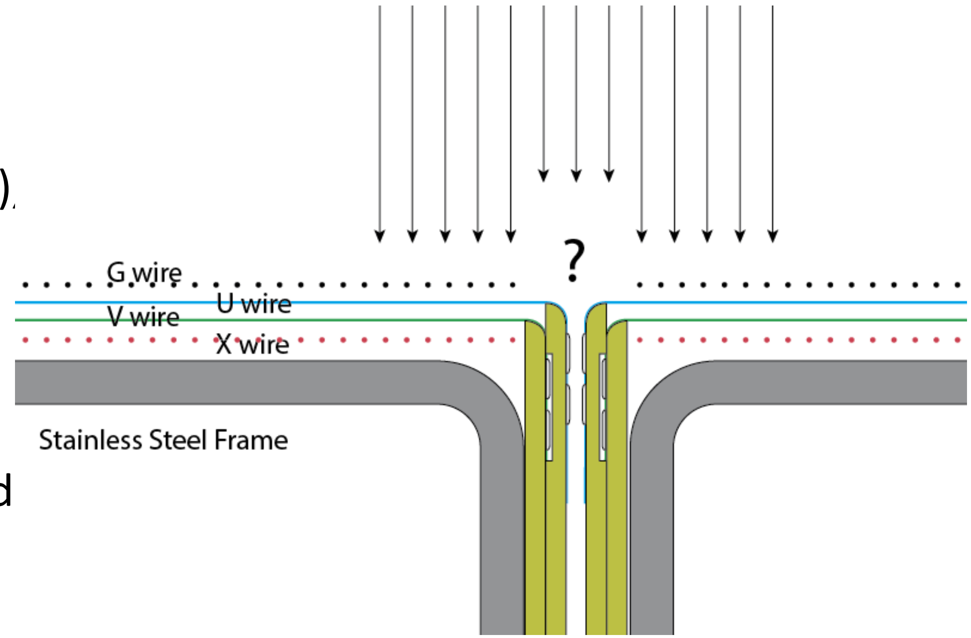


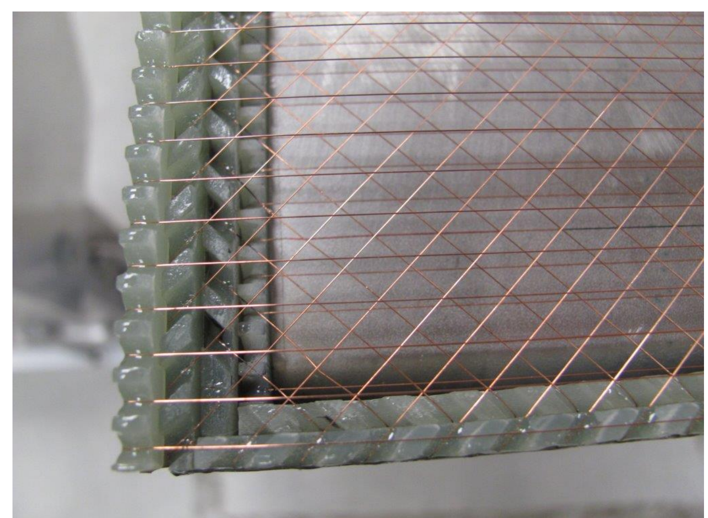
Dead Space Between APAs

The LBNE APAs use a set of 1/8" thick FR4 boards to bond the wires at the 3 butting edges of the APAs. On the long edges, there are two layers of such boards (U & V), while on the short edge, there are 4 layers (G,U,V & X).

The electric field near the gap between APAs is difficult to calculate due to the possible charging of insulating surfaces and a mix of conductors and insulators. As a result, the electron drift paths in that area are also difficult to predict.

Up to now, the drift volume above these gaps are considered inactive from the point of view of charge signal collection. Although we can expect mixed collection and induction type signal over the gaps. The collection type signal on the induction wires (U & V) may cause confusion in the pattern reconstruction.



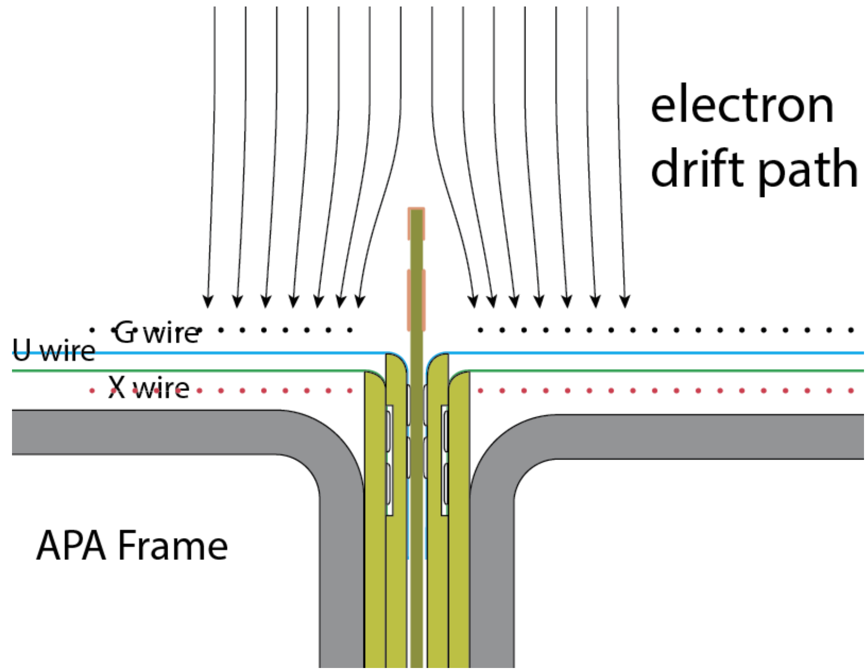


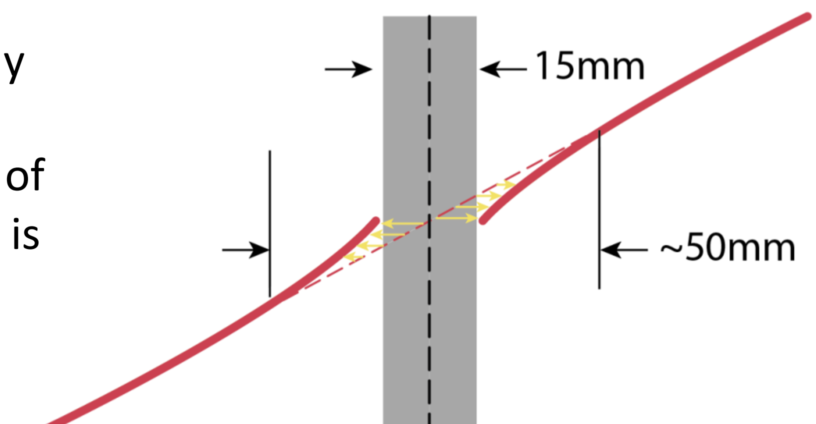
Field Shaping Near the Gap Between APAs

Instead of living with the uncertainties in the electron drift path near the gaps, we can instrument a simple field shaping electrode above the gap to better define the electric field above the gap:

Insert a printed circuit board with some strip pattern in the physical gap between the two APAs, and bias the strips in a voltage distribution such that the incoming electrons will be deflected away from this gap and land in the active region of the wire frame.

In this field configuration, we do not lose any electrons, but reconstructed inclined tracks will appear distorted at this gap. The width of this distorted region could reach ~5cm. This is a fixed distortion that can be easily mapped out and corrected.





Field Shaping Near the Gap Between APAs

Instead of living with the uncertainties in the electron drift path near the gaps, we can instrument a simple field shaping electrode above the gap to better define the electric

One field shaping board will be installed in the 35ton TPC between the smallest (3 unit high) APA and its neighbor with adjustable bias voltages.

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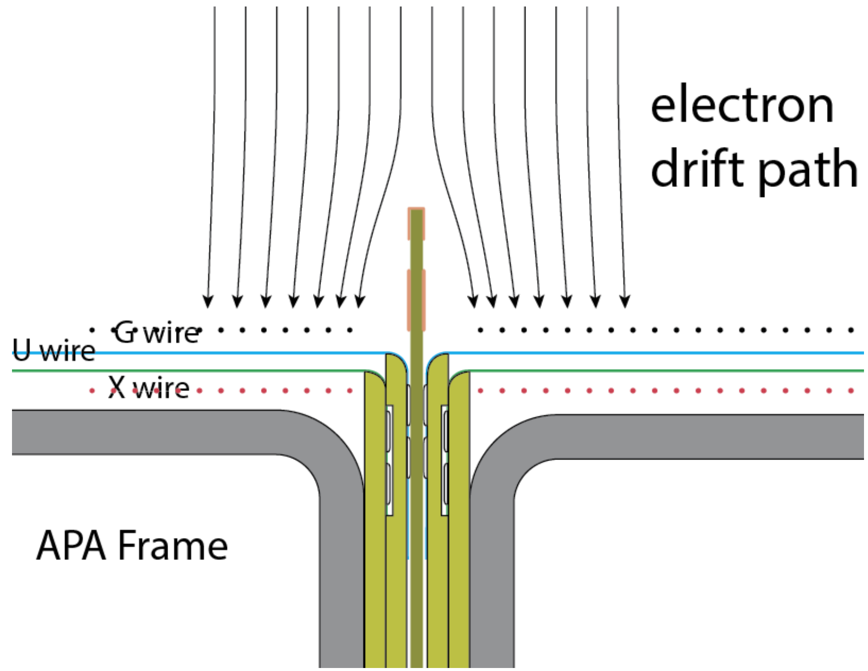
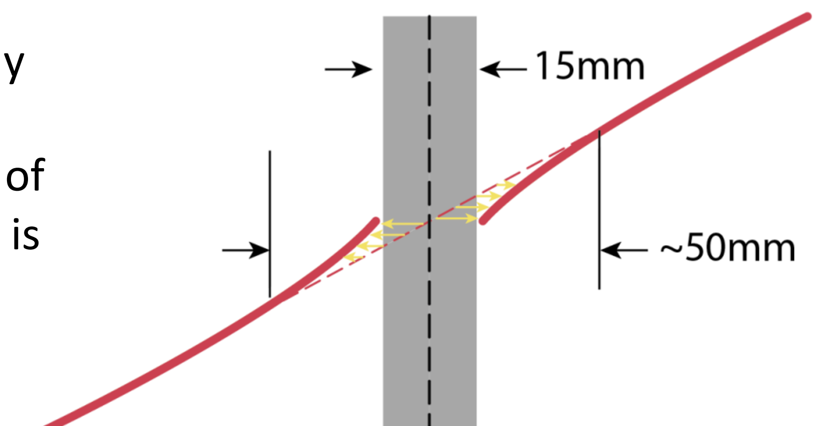




Bo Yu, BNL

Schedule (very preliminary)

- Vertical slice test (noise measurements in air): ongoing!
- TPC installation and debugging: ~April 1-20
- Cryo commissioning (piston purge, liquid fill) : May 4-27
- Detector commissioning/data taking: May 28-July 27

Deliverables . . .

- Cold noise, initial failures with readout - June 1
- Characterization of ASIC for different settings - ?? (S/N)
- Gap study – no earlier than august for preliminary results
- Effectiveness of field shaping in gaps – same as above
- Photon detector performance - ??
- ARTDAQ – mid-June?

Conclusions

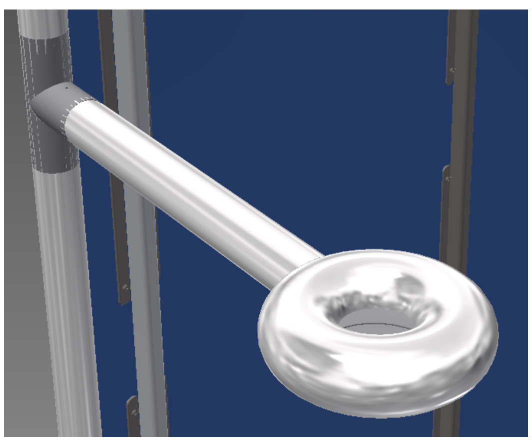
- 35ton results can be considered in the LAr1-ND design for common topics such a light detectors, FR4 field cage, APA gaps, cold electronics, and DAQ
- Significant investment by 35ton to generalize LArSoft algorithms (not yet complete), another opportunity to work together
  - multiple TPC reconstruction
  - photon detector simulation and reconstruction

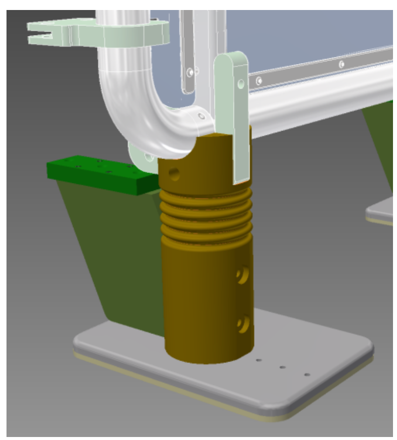
Crossing arrows between SBN avenue, LBN road, and Testbeam Lane benefit everyone!

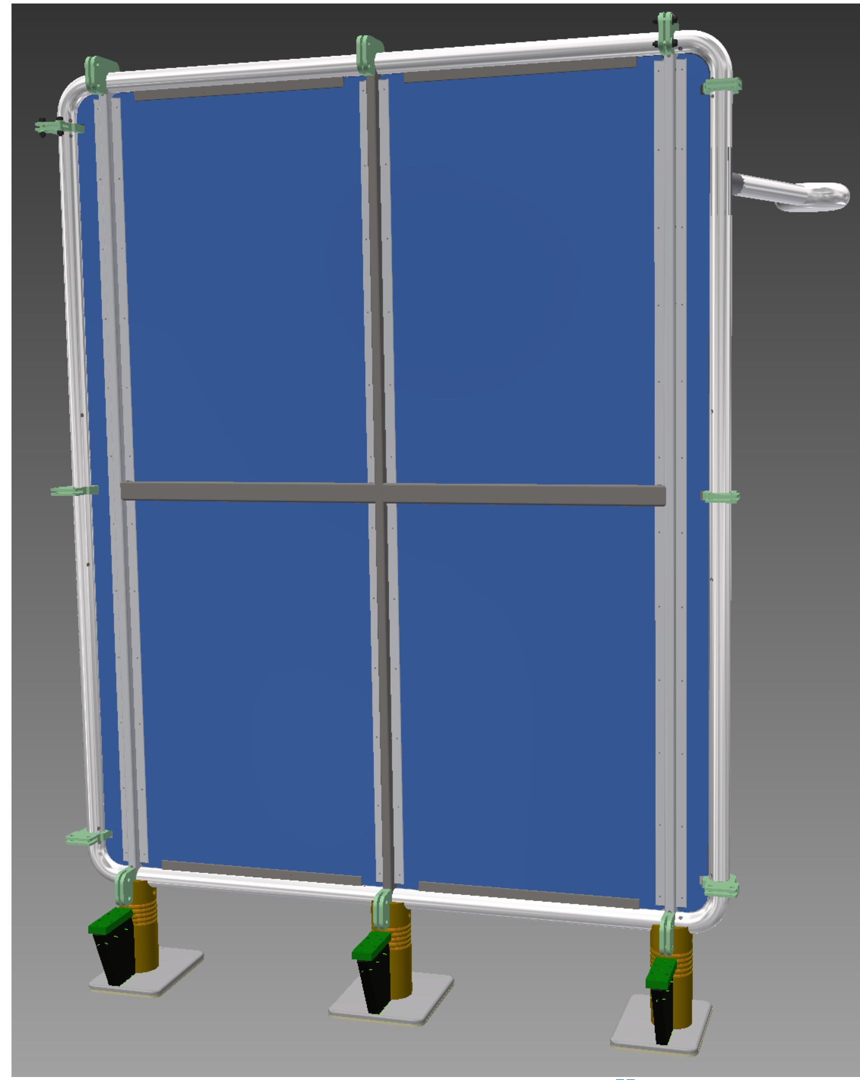
Backup slides

TPC Design Features: CPAs

- Two CPAs, one with HV receptacle.
- Bias from the short drift CPA tapped from the field cage
- Solid stainless steel cathode surfaces with rectangular frames to study local drift field non-uniformity in larger FD CPAs
- 2” OD tubular outer edges to minimize electric field
- 5 Fiber optic diffusors are mounted on the long drift CPA to provide calibration light pulses to the PDs (not shown)

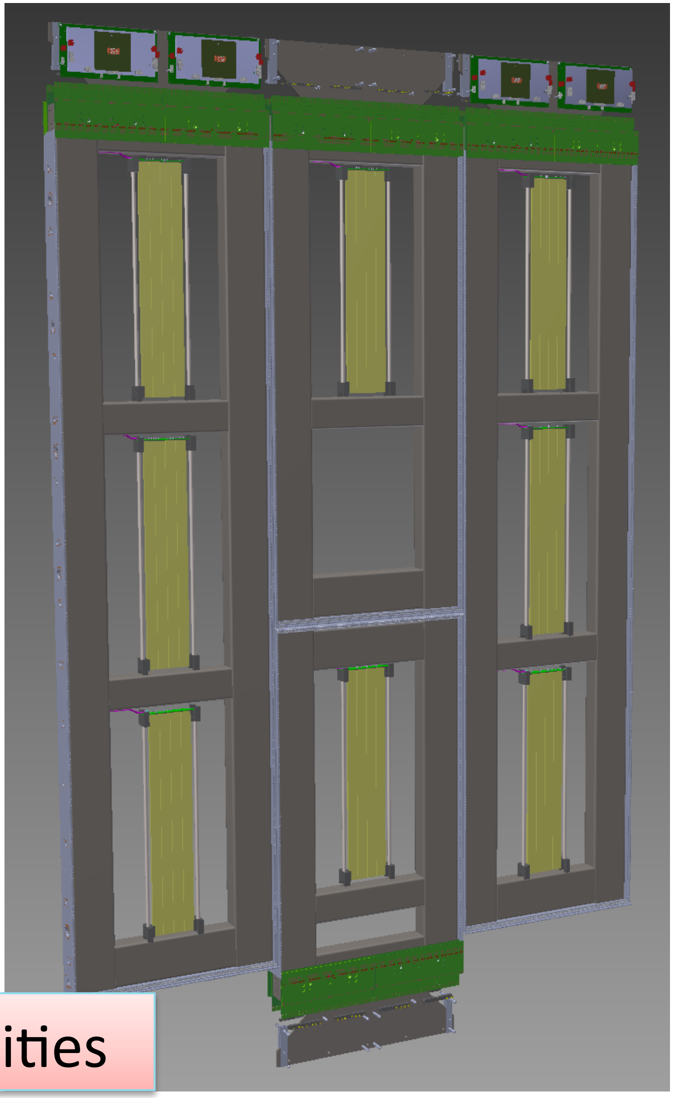






TPC Design Features: APAs

- 4 APAs to test APA horizontal and vertical interconnect features, and to study detector response at the horizontal and vertical gaps between APAs
- Wire wrapping angle based on the LBNE conceptual design: ±45° on the induction planes with small delta angles to break symmetry
- 8 embedded PDs with 3 different designs
- One APA does not have the grounded shielding mesh
- One long APA does not have intermediate wire support so long wire (2m) behavior can be studied
- All FEE boards on an APA are enclosed in a Faraday cage which also serves as containment for gas argon boil off from the electronics



FD design now 36 degrees to reduce ambiguities